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INVISIBLE SUN-SPOTS

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The vortex hypothesis, proposed in 1908, assumes that a sun-spot resembles a vast tornado in which electrified particles, due to ionization in the solar atmosphere, are rapidly whirled. The invariable presence of a magnetic field, caused by the revolving charges, confirms this view,¹ which is also supported by various other results of observation with the spectrograph and spectroheliograph. Subsequently it was found that most sun-spots are associated in pairs, of opposite magnetic polarity, in which the preceding (western) spot is usually the larger of the two. 61 per cent of 970 spots examined in the years 1915–1917 were of the bipolar type, while 33 per cent were unipolar. All but 11 per cent of the unipolar spots, however, showed a tendency toward the bipolar type, indicated by trains of calcium flocculi following (less often preceding) the single member.² Frequently such groups oscillate between the unipolar and bipolar types, one or more small spots appearing or disappearing within the mass of calcium flocculi. This peculiarity has led to a search for invisible spots, regarded as vortices giving appreciable magnetic fields, in which the cooling due to expansion is insufficient to cause perceptible darkening of the sun's surface.

Preliminary attempts to increase the contrast by the exclusive use of ultra-violet light did not prove successful, and a second method of detecting the slight difference of radiation by a heat-measuring instrument (bolometer, thermopile, or radiometer) or a photo-electric cell has not yet been tried. A third method, however, has given very satisfactory results. This consists of a simple device for rendering weak magnetic fields visible by their Zeeman effect.

The iron line λ 6173, observed in the second order of the 75-foot spectrograph of the 150-foot tower telescope, appears as a wide triplet in the strong magnetic fields of large sun-spots. In very small spots, where the field is weak, it is merely widened, but either edge can be cut off by a Nicol prism and quarter-wave plate mounted above the slit of the spectrograph. When searching for invisible spots a superposed half-wave plate, oscillated back and forth by a small electric motor, is used to reverse the action of the quarter-wave plate when it comes before the slit. While the motor is running, a promising region on the sun (marked by faculae or calcium flocculi) is caused to pass slowly across the slit, and the λ 6173 line is carefully watched. The presence of an invisible spot is betrayed by the apparent oscillation of the corresponding part of the line, due to the al-

ternate extinction of its red and violet edges. In this way magnetic fields of an intensity of 200 gausses can be detected.

A systematic search for invisible spots was begun by Mr. Ellerman and the writer on November 19, 1921, when two were found, with negative magnetic fields of 400 and 300 gausses, respectively, in the calcium flocculi following a positive single spot, No. 1920. One of these may not have belonged to this spot group, as it was about 4° south. Both were again detected by Mr. Ellerman on the following day, with slightly weaker fields. On November 21 only one could be found, and its position was now indicated by a faint marking, which on the following day became a visible spot, with a field-strength of 300 gausses. The other invisible spot to the south was not found, but another spot, preceding it and not previously detected magnetically, had also appeared.

Several other invisible spots have since been observed. The two small spots constituting the following member of No. 1919, which disappeared to the eye on November 25, were still detected magnetically by Nicholson on November 26 and on November 27, with positive fields of 300 and 200 gausses respectively. No. 1924, recorded from visual observations as a positive unipolar spot, was found by Ellerman on December 12 to be followed by a negative magnetic field of 200 gausses; both this and another invisible spot of negative polarity, observed by him on the following day, appeared as visible spots on December 14. On January 9, 1922 Ellerman observed a positive invisible spot (300 gausses) following the eastern negative spot of a regular bipolar group, No. 1932. No spot was observed in this position either before or after January 9. A small positive spot which appeared in group No. 1938 on January 23, 1922, though not observed either visually or magnetically on the two following days, was detected by Ellerman as a positive invisible spot (400 gausses) on January 26. Following the unipolar spot No. 1942 an invisible negative spot (300 gausses) was observed on February 6 by Ellerman and on February 26 he found a positive invisible spot (500 gausses) following No. 1945 (negative) and a negative one (300 gausses) following No. 1947 (positive). No visible spots were seen in either of these positions. On March 15 Nicholson detected a negative invisible spot (300 gausses) following No. 1953 (positive) in the region where the following spots had disappeared.

In an examination of our earlier magnetic records we have found nine other cases in which a local magnetic field was observed where no spot was recorded. Most of these were probably invisible spots, but as very small visible spots at the points in question might have escaped notice, and as the magnetic observations were not followed up, they are not included here.

The systematic observation of invisible spots, especially during the periods preceding and following the visible life of those that reach ma-

turity, should assist materially in revealing the cause of spot formation. Their frequency of occurrence is probably much greater than these first results suggest, as our winter observations have been seriously limited by exceptionally cloudy weather, poor seeing, and low solar activity.

¹ Hale, On the Probable existence of Magnetic Fields in Sun-spots. *Mount Wilson Contr.*, No. 30; *Astroph. J., Chicago*, **28**, 1908 (315-343).

² Hale, Ellerman, Nicholson, and Joy. The Magnetic Polarity of Sun-spots. *Mount Wilson Contr.*, No. 165; *Astroph. J., Chicago*, **49**, 1919 (153-178).

*COMPARISON OF THEORY WITH OBSERVATION FOR THE
MINOR PLANETS 10 HYGIEA AND 175 ANDROMACHE WITH
RESPECT TO PERTURBATIONS BY JUPITER*

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The perturbations of the minor planets 10 Hygiea and 175 Andromache, developed by Dr. Estelle A. Glancy and Dr. Sophia H. Levy on the basis of the revision of von Zeipel's formulae and tables of minor planets which have a mean motion approximately twice that of Jupiter, (Hecuba Group), have lately been severely tested by comparison of recent observations with the computed places, for which the numerical work was performed by Dr. H. Thiele. This revision of von Zeipel's theory will soon appear as the third memoir of Volume 14 of the *MEMOIRS OF THE ACADEMY*. The results of these comparisons are highly encouraging and prove that the revised tables for the Hecuba Group more than meet the practical requirements of a satisfactory representation of the motion of the minor planets belonging to this group. The preliminary conclusions communicated to the Academy at the annual meeting of 1916 in my general report on the perturbations and tables of the minor planets discovered by James C. Watson are thereby fully verified.

Hygiea was discovered on April 12, 1849 by Gasparis. The most accurate of the earlier orbits computed was that by von Zech, which was based on the elements of d'Arrest and the general perturbations, developed by Hansen's method, by Jupiter, Saturn, and Mars, extending over eight oppositions. Since von Zech's death in 1864, his computations have been kept in the Recheninstitut at Berlin and were used by von Zeipel in connection with the application of his approximate perturbations for the Hecuba Group. Von Zech's computations have been continued from year to year at the Berlin Recheninstitut until 1873, up to which time they represented the motion of Hygiea with considerable accuracy. In the Berlin *Jahrbuch* for 1876 new elements by E. Becker are given. These